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A NEW RAPID EVAPORATOR FOR MAKING HIGH-GRADE MAPLE SIRUP

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Introduction

An important factor in the grading of maple sirup is color (1); lighter colored sirups usually command a premium price. In general, the lightest sirups are made from first-run maple sap, the sirup becoming darker as the season progresses. Using the processing techniques and equipment available at the present time, the producer has little control over the color of his final product. In order to remedy this and to increase the production of lighter grade sirup, a high-speed steamheated tube-type evaporator has been developed at this laboratory. For brevity it is referred to here as the R.A.E.--Rapid Atmospheric Evaporator.

The use of the R.A.E., coupled with its holding chamber, permits control of color development. Late-season sap, which would give lower grade sirups, can now be made into lighter premium grade sirup. It is recognized that the terms "early-season sap" and "late-season sap" are not definitive. They refer in these experiments to saps which when processed in an open pan give respectively light (e.g., color index** 0.42) and dark (e.g., color index 0.83) sirups. "Late-season sap" was tapped from the same "bush" as "early-season sap", but about 15 days later.

Since the new evaporator requires steam it would not be suitable for the average farm. It would logically be used in a centrally located cooperative or plant where it would convert maple sap, which had been partially concentrated on the farm, to sirup. Though sap can be evaporated to sirup in a few seconds by a single pass through the R.A.E., partial concentration to about 20% solids by open pan on the farm, and then finishing to sirup in the R.A.E., is more advantageous.

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**Color index, $A^{86.3\%}_{1\ cm.} = A_{450}\ (86.3/bc)$, where A_{450} is the observed absorbance at 450 μ, b is the depth of solution in centimeters (1 cm. in these experiments), and c is the grams of solids as sucrose per 100 ml. as determined on an Abbe refractometer.

Limitations of The Present Method of Sirup Making

The major drawback of the conventional open-pan method of making maple sirup is the lack of control over color and flavor. When sirup is made in the open pan, two operations are carried out simultaneously: (1) removal of water and (2) color and flavor development. Better control of color and flavor would result if their development were separated as far as practicable from concentration.

Another problem in operating a sirup pan is control of drawoff. Continuous drawoff of 65.5° Brix sirup is not feasible with small pans because the finished sirup flows at a very slow rate with respect to the rate of sap feed. Even with large pans close attention and considerable skill are required if a sirup of uniform solids is to result. Periodic drawoff causes nonuniformity and unstable conditions in the pan. Some operators have found it desirable to drawoff sirup before it is fully concentrated, finishing it batchwise by boiling it in a separate container.

Maintenance of uniform sirup quality throughout the season is a further problem with the conventional system. As the season advances the character of the sap changes. Late-season sap gives darker, less valuable sirup for a given heat exposure than early-season sap. Yet because the solids content of the sap may remain the same, the same heat exposure is required to concentrate it to sirup. Thus dark sirup commonly results.

The foregoing difficulties can be largely overcome by use of the rapid atmospheric evaporator.

The Rapid Atmospheric Evaporator

Extensive work has been done at this Laboratory on rapidly concentrating fruit juices at atmospheric pressure without heat damage. Some of the principles used in these engineering studies have been applied to the design of maple-sirup equipment. The result has been a simple apparatus from which sirup of high quality can be drawn off continuously. Evaporation is carried out in steamheated tubes so rapidly that the heat effects are very slight. It has recently been shown that in normal open-pan evaporation the time required to concentrate from about 45% sugar to standard density is about 40 minutes, nearly one-third of the entire time in the pan. In the high-speed evaporator the time is shortened to a few seconds for this stage of the evaporation. Investigations made at this Laboratory by Willits and coworkers (2) on color development of maple sirup showed that length of time of boiling and solids content of sirup were important factors in color development. Above a sugar content of 45% the rate of color formation begins to rise rapidly, and this is one of the reasons for the difficulty of controlling the color in the open pan. In the R A E. the sirup is passed almost instantaneously through the higher concentration stages where color development is rapid.

Description

A pilot-plant size rapid atmospheric evaporator for maple sirup is shown in Figure 1. The path of the sap through the evaporator is shown in the flow sheet (Figure 2). The unit consists of a tank A which holds the feed (sap or partial concentrate). From this tank the feed is supplied at a constant rate by pump B through a flowmeter C into a preheater D. The preheater is a 30-in. steam-jacketed tube, 1/8 in. outside diameter, made of 316 stainless steel. A dial thermometer E at the preheater outlet indicates the temperature of the feed as it leaves the preheater and enters the vaporizer tube F, another 30-in. steam-jacketed tube made of 316 stainless steel, but with an outside diameter of 1/2 in. In Figure 1, vaporizer F is directly behind preheater D. The larger bore tube is used in the vaporizer section because of the enormous expansion in volume that occurs on vaporization. The steam pressure to the preheater and vaporizer jackets is controlled by regulating valve J. The mixture of vapor and sirup leaves the vaporizer at a very high speed past the stem of a dial-type maple-sirup thermometer G. This thermometer (3) was developed by C. O. Willits of this Laboratory for use in open-pan evaporators. The mixture of vapor and sirup then enters separator H from which the vapor escapes at the top and the sirup flows to a receiver. A bypass valve permits the sirup to be directed to a steamheated holding chamber I where it can be held hot to intensify flavor if desired. Ordinarily the sirup as discharged from the separator will have only the highly esteemed, delicate maple flavor. Retaining it hot in a holding chamber will intensify this flavor, but may also tend to impart a slight caramel taste to the sirup. In actual practice a holding chamber would probably not be necessary. Color and flavor of early-season sirup could be increased if necessary by concentrating in the open pan to a higher degree, e.g., 40° Brix, or the very light-colored, delicately flavored sirup could be held to upgrade the late-season product by blending.

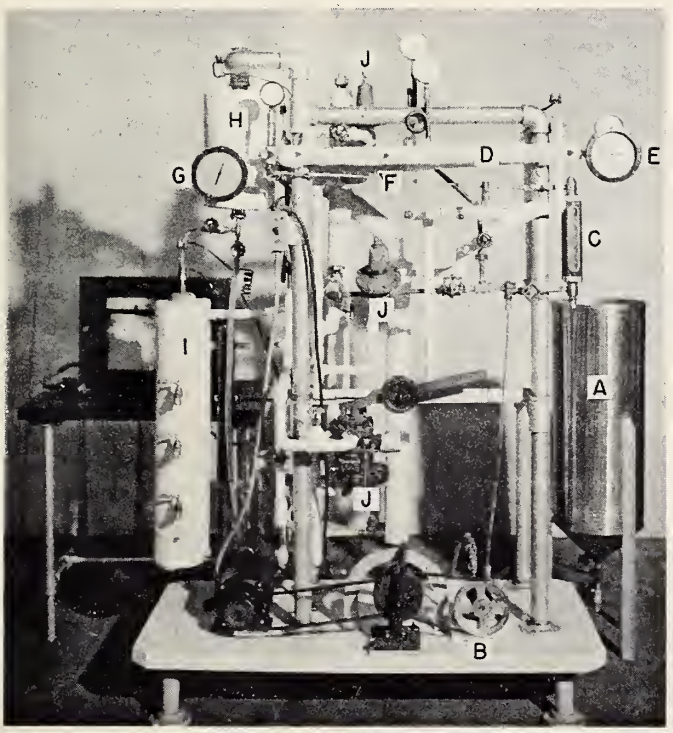


Figure 1

RAPID ATMOSPHERIC EVAPORATOR FOR PILOT-PLANT USE

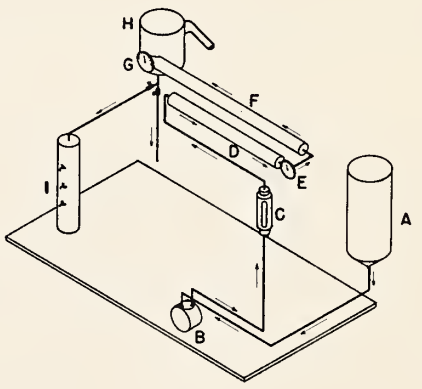


Figure 2

DIAGRAM OF RAPID ATMOSPHERIC EVAPORATOR

Experimental Operation

Sap and partial concentrates were concentrated to sirup in the R.A.E. The partial concentrates of varying sugar content (18-31%) were prepared from early- and late-season sap in an oil-fired 50-gallon-per-hour conventional open pan which was installed in a farm sugar house. These partial concentrates were hot packed to insure their sterility and stored at 0° F. pending their use.

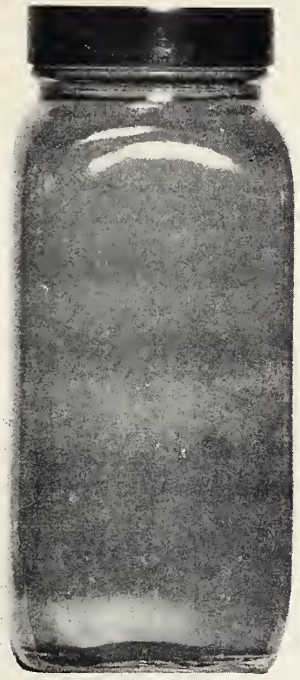
Prior to evaporation, the partial concentrates were filtered into the feed tank through a felt cloth of the type usually used in filtering maple sirup. This filtration removes the sugar sand which would have a harmful abrasive effect on the pump.

It was then pumped from the feed tank to the preheater inlet at a constant rate, in the range of from 1.3 to 1.5 gallons per hour, as indicated by a flow-meter in the line. This meter had been previously calibrated for sugar-water solutions of the same Brix range as the maple sirup partial concentrates to be tested. The feed rate was controlled by adjusting the opening of a valve in the flowmeter inlet line. In earlier runs the feed was heated to 190-200° F. in the preheater, but on prolonged operation at this temperature, scale formed on the vaporizer wall, decreasing the heat-transfer rate. This was overcone by heating the feed to 216-218° F. in the preheater. The feed, when superheated to this higher temperature, flashes more rapidly into vapor on entering the vaporizer, scouring the wall, and preventing scale formation. To attain this higher temperature in the preheater a jacket steam pressure of 12 to 15 pounds per square inch was found to be adequate.

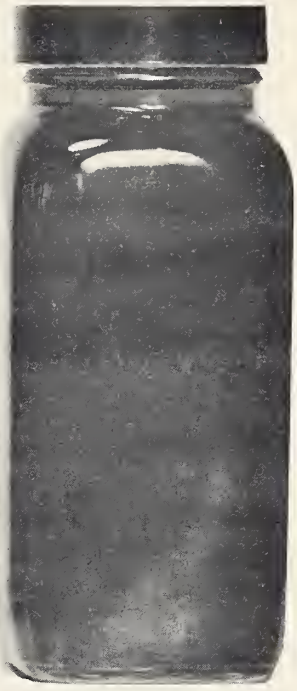
For the evaporation of the required amount of water, the vaporizer was heated with steam at 55 to 60 pounds per square inch. A dial thermometer at the outlet of the vaporizer indicated the sugar content of the product. By checking the sugar content frequently by a hand refractometer and observing the dial thermometer reading, it was found that as a result of the superheating which occurs in the vaporizer a thermometer reading 5 to 7° above the usual "sirup" reading indicated 66° Brix sirup. Once sirup of correct density was flowing, all the operating conditions (steam pressures and feed rate) were kept constant, and the sirup was collected continuously in receivers set in an ice bath to minimize any further heat effects.

Color and Flavor of R.A.E. Sirups

As might be expected early-season sap which gave U.S. Fancy sirup in the open pan gave the same grade in the R.A.E. The color indices of the R.A.E. and open-pan sirups were 0.32 and 0.42 respectively. Partial concentrates of 18 to 25% sugar made from late-season sap and then finished in the rapid atmospheric evaporator yielded U.S. Fancy maple sirup (color index 0.50). The same sap made into sirup in the open pan gave a product with a color index of 0.83. See Figure 3. Late-season partial concentrates above 25%, e.g., 31% solids, yielded a sirup that was a trifle darker than U.S. Fancy (0.60). Therefore, in order to produce light sirup from late-season sap, concentration in the pan should not go above about 25% sugar.



Rapid Atmospheric
Evaporator
Color Index 0.500



Open Pan
Color Index 0.830

Figure 3

Sirup from Late-Season Sap

The flavors of the sirups produced in the rapid atmospheric evaporator were compared with a commercial U.S. Fancy sirup and two other darker sirups which contained different amounts of caramel. The sirups produced by the R.A.E. possessed no detectable caramel flavor, had no off-flavors, and possessed a true, delicate maple flavor characteristic of commercial U.S. Fancy sirup.

Advantages of Using Partial Concentrates

Most of these experiments were conducted using partial concentrates (e.g., 20% sugar) because this is the most practical means of using the R.A.E. Some work, however, was done with sap, which yielded an essentially colorless and flavorless sirup that would have required further heat treatment to produce a satisfactory maple sirup. There are a number of advantages of using partial concentrates in the R.A.E., among which are the following:

1. It permits the farmer to make effective use of his existing pan.

2. It facilitates control of pan operation and permits continuous draw-off because product (partial concentrate) volume is larger and accurate control of solids is not necessary.

3. Bulk is reduced to about one-tenth that of sap, reducing storage and subsequent processing costs.

4. The product is stable permitting temporary storage at the central sirup plant.

Practical Applications

If a rapid atmospheric evaporator were set up for cooperative use, the system of operation might be as follows. The farmers would evaporate the sap to about 20% solids in their conventional pans. Pan capacity would be thereby increased about 10%. Since accurate control of sugar concentration is unnecessary, continuous drawoff becomes practicable. This sap, now reduced to about one-tenth its original volume, is sterile. It can be collected conveniently in previously sterilized milk cans. The farmer would presumable be credited on the basis of the sugar content of the partial concentrate delivered to the cooperative. There various lots would be blended and filtered to remove sugar sand and foreign matter. The blend of filtered partial concentrates of uniform Brix would be then processed into sirup in the R.A.E. The holding chamber would be employed, if at all, only at the beginning of the season when it might be required to enhance the very delicate flavor or even to darken the color to that of commercial U.S. Fancy grade.

The unit described in this paper is of pilot-plant experimental size and handles 1-1/2 gallons per hour of feed. Construction drawings including a bill of material of a larger unit having a capacity of about 100 gallons per hour feed may be obtained from the Eastern Utilization Research Branch, Philadelphia 18, Pennsylvania.

References

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2. C. O. Willits, W. L. Porter and M. L. Buch, "Maple Sirup V. Formation of Color During Evaporation of Maple Sap to Sirup", Food Res., Vol. 17, 482-486 (1952).

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Acknowledgment

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